International Journal of Engineering Research & Management Technology
ISSN: 2348-4039
Volume 8, Issue-3 May-June 2021
Email: editor@ijermt.org
www.ijermt.org

OPTIMIZATION OF MACHINING PARAMETERS AFFECTING KERF, M/C TIME AND CUTTING SPEED OF AL6063-T6 IN WEDM OPERATION

Makkenaveer Anjaneyulu
Research Scholar
Dept. of Mechanical Eng.
OPJS University, Churu, Rajasthan

Dr. Deepak Dalal
Assistant Professor
Dept. of Mechanical Eng.
OPJS University, Churu, Rajasthan

Abstract

Wire-cut EDM is one of the modern machining processes. It plays a substantial role to cut complex and intricate shapes of components in all conductive, hard and thicker materials. A suitable modeling can improve the machining performance and the product accuracy. Surface Response Methodology (RSM) coupled with grey relation analysis method has been proposed to predict the performance characteristics namely the surface roughness, material removal rate, machining time, cutting width and cutting speed of WEDM on the alloy AL6063-T6 work-piece material with input parameters such as pulse on time, pulse off time, wire tension, wire feed and dielectric flow flushing pressure. ANOVA is applied to determine significance of the input parameters for optimizing the grey relation grade.

Keywords

Wire-cut EDM, Response surface methodology, grey relation analysis, ANOVA, WEDM

Nomenclature

EDM - Electric Discharge Machining, ***RSM*** - Response surface methodology, ***ANOVA*** - Analysis of Variance, ***GRA*** - grey relational analysis, ***Ra*** - surface roughness(µm), ***MRR*** - material removal rate (mm^3/min), T_m - Machining time (min), ***CS*** - cutting speed (mm/min), ***kerf*** - cutting width (mm), T_{on} - Pulse on time (µs), T_{off} - Pulse off time(µs), ***WT*** - wire tension (N), ***WF*** - wire feed (mm/min), ***P*** - dielectric flow flushing pressure (kg/cm^2).

1. INTRODUCTION

Wire electrical discharge machining (WEDM) is Non-traditional machining processes have changed the whole scenario of manufacturing industries. Traditional machining processes are rapidly replaced by non-traditional methods for achieving better production rates and quality. WEDM process involves the erosion effect by rapid repetitive and discrete spark discharges between the wire tool electrode and work piece in a liquid dielectric medium. Manufacturing the parts of high quality at high production efficiency is the main objective of WEDM process.

Selecting the appropriate machining parameter for high quality product is very difficult. Much research is not found in the field of WEDM to find the optimum parameter; In the present research, GRA is used to find the response variables of WEDM. An attempt is made by Magesh M et.al. (2017) for optimization of wire-EDM process parameters to calculate MRR and measure surface finish on SS410 material.[1]. Amit Kumar et.al. (2018) a face centred cubic design is used for conducting experiments on high-speed steel (HSS) M2 grade work-piece material. The optimal condition for the machining parameter was obtained using the grey relation grade. [2].

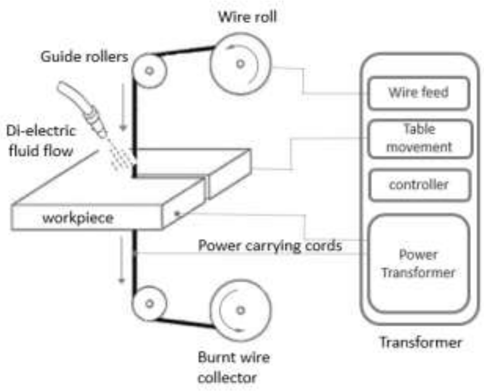


Figure 1.1: Line diagram of Wire-cut EDM process.

Kosaraju Satyanarayana et.al. (2020) the paper deals with the reviews of the researchers that have been performed over cryogenic treated WEDM process. Effect of performance characteristics like pulse on, pulse off, current, voltage, wire tension, wire feed is discussed with relation to material removal rate, tool wear rate and surface roughness evolved. [3]. Manpreet Singh et.al. (2013) in this paper a review of the recent work has been done and parameters that effects the machining performance of WEDM are discussed. [4]. Junaid Ali Abbasi et.al. (2017) in this work, surface roughness model has been developed for high-strength low-alloy (HSLA) steel and experiments using factorial designs to develop relationship between SR and WEDM process parameters. Accuracy of the proposed model has been confirmed through residual analysis and validation experiments. [5]. Mandeep Kumar et.al. (2016) the material removal rate of Inconel X750 subjected to wire EDM is studied and optimized by using Taguchi technique. The ANOVA is carried out to determine the level of importance of the machining parameters on the MRR. [6]. Pratik A. Patil et.al. (2014) it deals with Response Surface Methodology approach for maximizing the material removal rate in wire electrical discharge machining. The investigated machining parameters were wire tension, pulse on time and peak current. Machining was carried on AISI D2 cold work steel. The effect of the parameters on MRR was determined by analysis of variance (ANOVA). Regression analysis was done and a second order mathematical model was fitted for MRR considering the parameters and their significant interactions. [7]. Kumaravel Subramaniam et.al. (2020) the stir casting technique was used to produce 10 wt% Sio2 aluminium matrix composites as reinforcement. Three process parameters such as pulse on time, pulse off time, and current were considered. The orthogonal L9 section of Taguchi was used as the model of the experiment. ANOVA was performed to detect the important parameter affecting surface roughness. [8]. Asfana Banu et.al. (2017) the study is on effect of WEDM process parameters on surface roughness and kerf on stainless steel using distilled water as dielectric fluid and brass wire as tool electrode. The analysis revealed that off time has major influence on surface roughness and kerf. [9]. Neeraj Sharma et.al. (2013) investigation is to study the effect of parameters on metal removal rate for WEDM using HSLA as work-piece and brass wire as electrode. It is observed that metal removal rate and surface roughness increase with increase in pulse on time and peak current. Metal removal rate and surface roughness decreases with increase in pulse off time and servo voltage. RSM is used to optimize the parameters MRR and Ra. {10]. Kimgshuk Mandal et.al. (2020) experimental investigation has been carried out for appropriate selection of process parameters in WEDM of Al 7075. It has been perceived that pulse on time (T_{on}), arc on time (A_{on}) pulse off time (T_{off}), arc off time (A_{off}), servo sensitivity (S_c), wire tension (W_t) and servo voltage (S_v) are the major influencing factors on machining speed (V_c), corner error (C_e) and surface roughness (R_a) for this alloy. [11]. Nagarajan Lenin et.al. (2021) In this work, wire electrical discharge machining (WEDM) of aluminium (LM25) reinforced with fly ash and boron carbide (B4C) hybrid composites was performed to investigate the influence of reinforcement wt% and machining parameters on the performance characteristics. [12].

2. MATERIAL AND WORKING METHOD

Taguchi technique was utilised for design experiments, the various input parameters varied during the experiments such as Pulse on time (Ton), Pulse off time (Toff), Wire tension (WT), Wire feed (WF) and dielectric flow flushing pressure (P). The effect of these input parameters were studied on the responses kerf (CW), Machining time (M_T) and cutting speed (CS). The main objectives of present study are

- To find significant factors on responses
- To estimate percentage contribution of input parameters on responses
- To study the effect of input factors on responses
- To optimize multi responses by setting predict values to input parameters.

Taguchi method

L8 orthogonal Array of matrix (5factor, 2level array) was used for design and conduct experiments shown in Table 2.1.

S.no.	Independent Variables	Notation	Units	Levels	
				L1	L2
1	Pulse on-time	T_{on}	µs	4	8
2	Pulse off-time	T_{off}	µs	7	14
3	Wire tension	WT	N	7	14
4	Wire feed	WF	mm/min	4	6
5	Flushing pressure	P	Kg/cm^2	2	6

Table 2.1: Selected factors and their levels for machining of AL6063-T6

Selection of Material

Material used for investigation is Aluminium alloy AL6063-T6. The dimension of sample is 130x80x20mm.

Experimental setup

Experiments were conducted on wire EDM machine (Excetek EX400 Series Submerged Type CNC wire-cut EDM). The WEDM machine tool has the following specifications:

- X/Y travel 400x300mm
- Z travel 220mm
- U/V travel 80x80mm
- Taper angle up to +/-22deg./80mm
- Wire dia. 0.15 to 0.3mm

Figure 2.1: WEDM Operation, Work-piece after machined and Ra measurement System

A 0.25mm dia. Milscut brass wire by MANAN Associates was used as cutting electrode and Ra is measured using Taylor Hobson Surface Profilometer.

3. ANALYSIS AND DISCUSSION

Result data was tabulated shown in Table 3.1 and the data was analysed using RSM available in statistical software Minitab19.

S.NO	TON (MS)	TOFF (MS)	WF (MM/MIN)	WT (N)	P (KG/CM^2)	KERF (MM)	M/C TIME (MIN)	CUTTING SPEED (MM/MIN)

1	4	7	4	7	2	0.77	8.56	4.70
2	4	7	4	14	6	0.92	8.20	4.65
3	4	14	6	7	2	0.91	10.49	3.45
4	4	14	6	14	6	1.01	11.23	3.45
5	8	7	6	7	6	0.73	7.33	5.0
6	8	7	6	14	2	0.92	7.36	5.00
7	8	14	4	7	6	1.04	8.04	4.85
8	8	14	4	14	2	1.03	7.40	4.85

Table 3.1: Experimental results data

RSM is a collection of mathematical and statistical techniques useful for analysing problems in which several independent variables influence a dependent variable or response, and the goal is to optimize this response.

In many experimental conditions, it is possible to represent independent factors in quantitative form as given in Equation 1, then these factors can be thought of as having a functional relationship with response as follows:

Y = φ {x1, x2, x3, ………..., xk} +/- er (1)

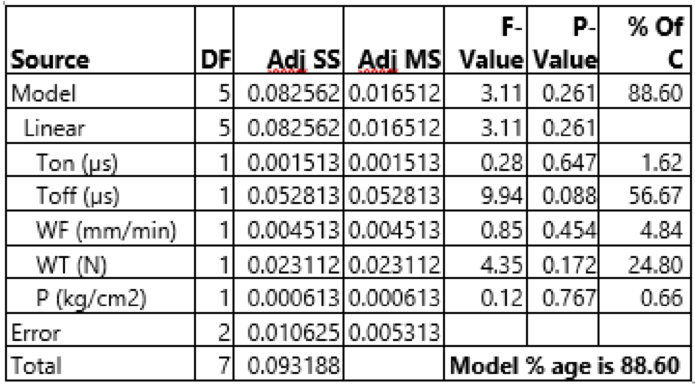
This represents the relation between the response Y and x1, x2, ……..., xk of k quantitative factors. The function φ is called response surface or response function. The residual er measures the experimental errors.

A. Regression analysis

The experimental results were used to develop a mathematical model, for expressing the relation between process parameters and responses. The coefficients of mathematical models are computed using method of multiple regressions.

1.) KERF verses control factors

Analysis of Variance



Source	DF	Adj SS	Adj MS	F-Value	P-Value	% Of C
Model	5	0.082562	0.016512	3.11	0.261	88.60
Linear	5	0.082562	0.016512	3.11	0.261	
Ton (µs)	1	0.001513	0.001513	0.28	0.647	1.62
Toff (µs)	1	0.052813	0.052813	9.94	0.088	56.67
WF (mm/min)	1	0.004513	0.004513	0.85	0.454	4.84
WT (N)	1	0.023112	0.023112	4.35	0.172	24.80
P (kg/cm2)	1	0.000613	0.000613	0.12	0.767	0.66
Error	2	0.010625	0.005313			
Total	7	0.093188	Model % age is 88.60			

Table3.2: ANOVA for Kerf vs. Control parameters

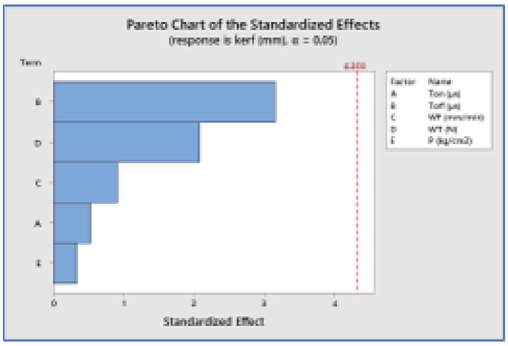


Figure3.1: Pareto Chart of Standardized Effects of Kerf vs. Control Parameters

kerf (mm) = 0.571+ 0.0069xTon (µs)+ 0.02321xToff (µs)- 0.0238xWF (mm/min) + 0.01536xWT (N)+ 0.0044xP (kg/cm2) .... (2)

2.) M/c Time verses control factors

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% Of C
Model	5	15.1355	3.02709	14.60	0.065	97.33
Linear	5	15.1355	3.02709	14.60	0.065	
Ton (µs)	1	8.7153	8.71531	42.03	0.023	56.05
Toff (µs)	1	4.0755	4.07551	19.65	0.047	26.21
WF (mm/min)	1	2.2155	2.21551	10.68	0.082	14.25
WT (N)	1	0.0066	0.00661	0.03	0.875	0.04
P (kg/cm2)	1	0.1225	0.12251	0.59	0.522	2.67
Error	2	0.4147	0.20736			
Total	7	15.5502		**Model % age is 97.33**		

Table 3.3: ANOVA for M/c Time vs. Control Parameters

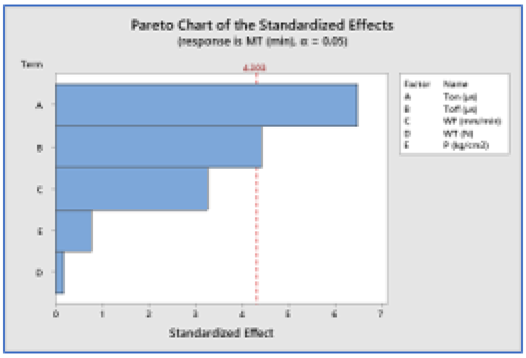


Figure 3.2: Pareto Chart of the Standardized Effects of M/c Time vs. Control Parameters

MT = 6.77- 0.5219xTon (µs)+ 0.2039xToff (µs)+ 0.526xWF (mm/min) -
(min) 0.0082xWT (N)+ 0.0619xP (kg/cm2) .... (3)

3.) Cutting Speed verses control factors

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value	%Of C
Model	5	2.89406	0.57881	108.95	0.009	99.63
Linear	5	2.89406	0.57881	108.95	0.009	
Ton (µs)	1	1.32031	1.32031	248.53	0.004	45.45
Toff (µs)	1	1.08781	1.08781	204.76	0.005	37.45
WF (mm/min)	1	0.47531	0.47531	89.47	0.011	16.36
WT (N)	1	0.00781	0.00781	1.47	0.349	0.27
P (kg/cm2)	1	0.00281	0.00281	0.53	0.543	0.10
Error	2	0.01062	0.00531			
Total	7	2.90469		**Model % age is 99.63**		

Table 3.4: ANOVA for Cutting Speed vs. Control Parameters

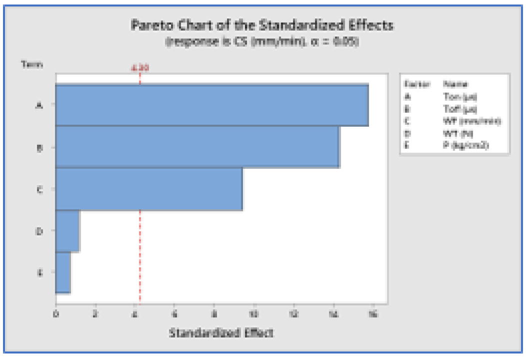


Figure 3.3: Pareto Chart of the Standardized Effects of Cutting Speed vs. Control Parameters

CS = 5.631+ 0.2031xTon (µs)-
(mm/min) 0.10536xToff (µs)-
0.2438xWF (mm/min)-
0.00893xWT (N)
+ 0.0094xP (kg/cm2)

B. Contour plots

1.) KERF vs Control Parameters

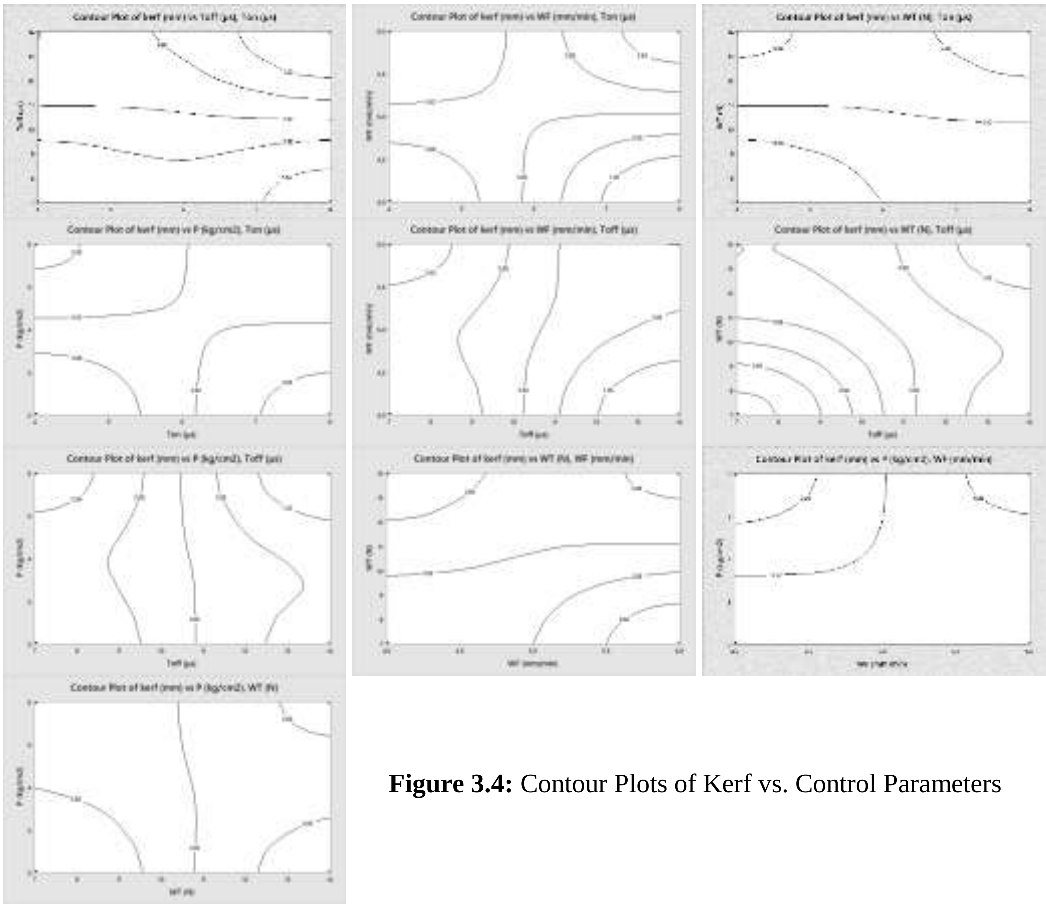
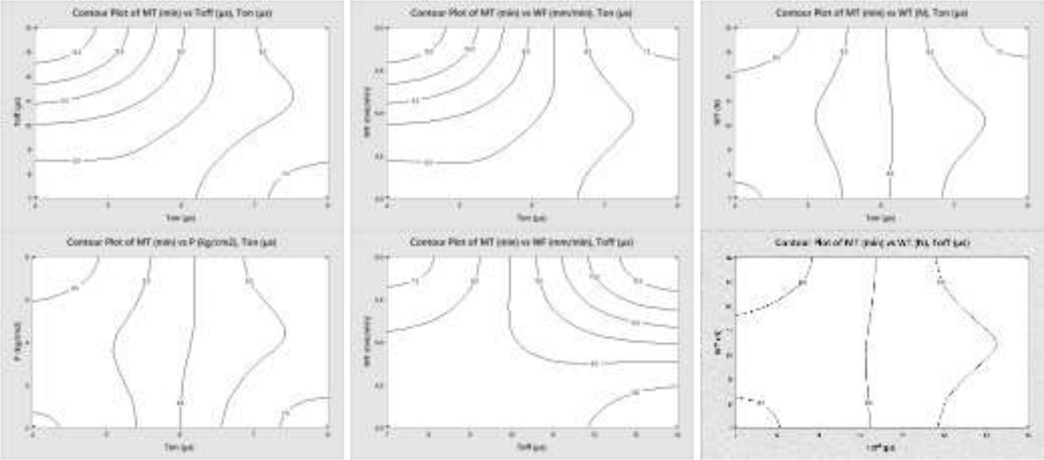


Figure 3.4: Contour Plots of Kerf vs. Control Parameters

2.) M/c Time (min) vs Control Parameters



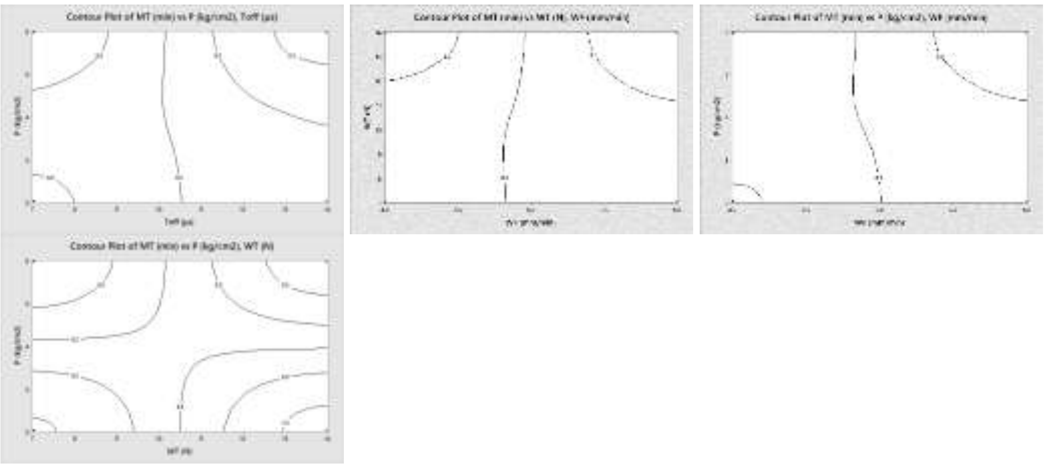


Figure 3.5: Contour Plots of M/c Time vs. Control Parameters

3.) Cutting Speed (mm/min) vs Control Parameters

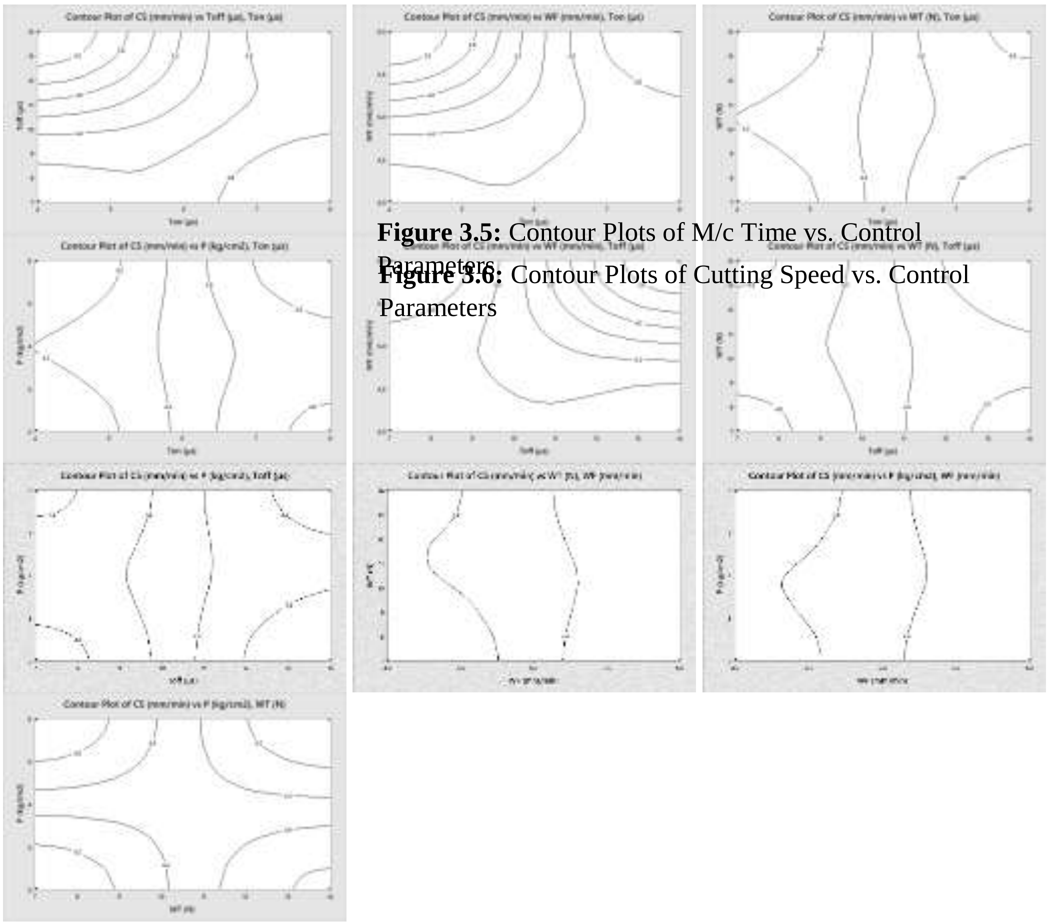
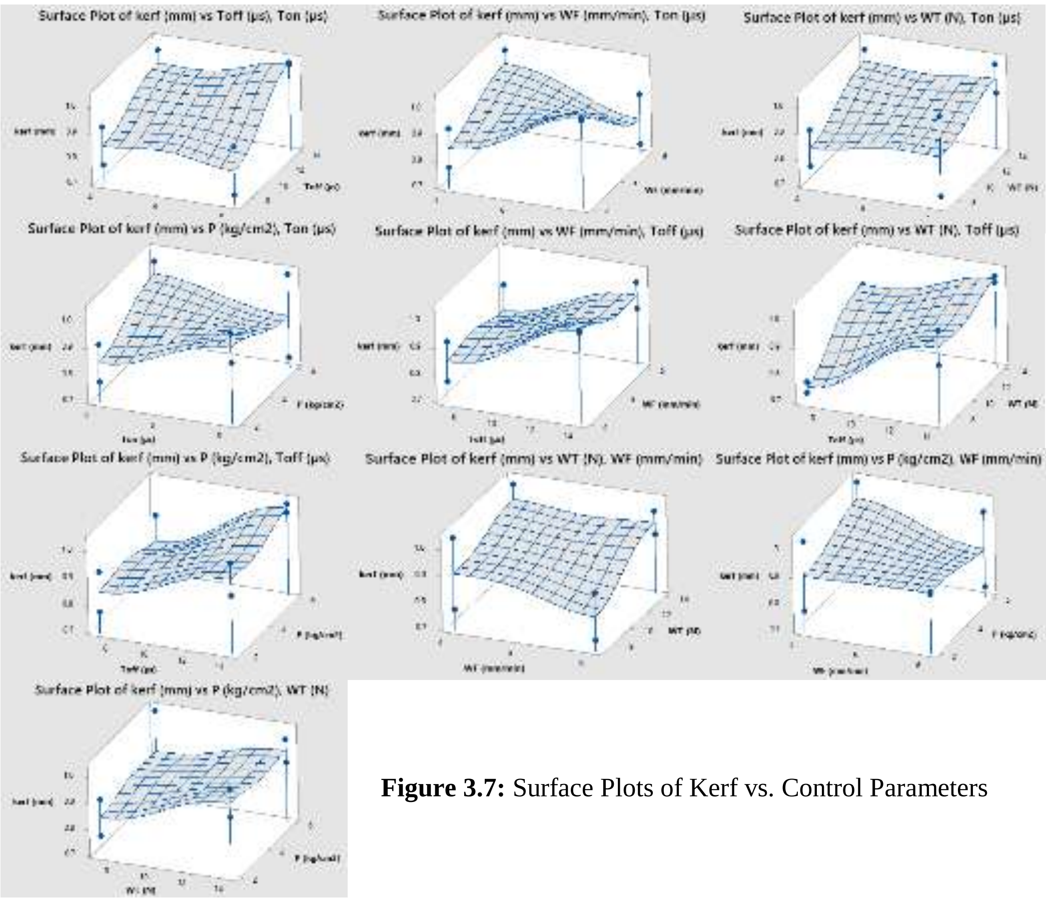


Figure 3.6: Contour Plots of Cutting Speed vs. Control Parameters

C. Surface plots

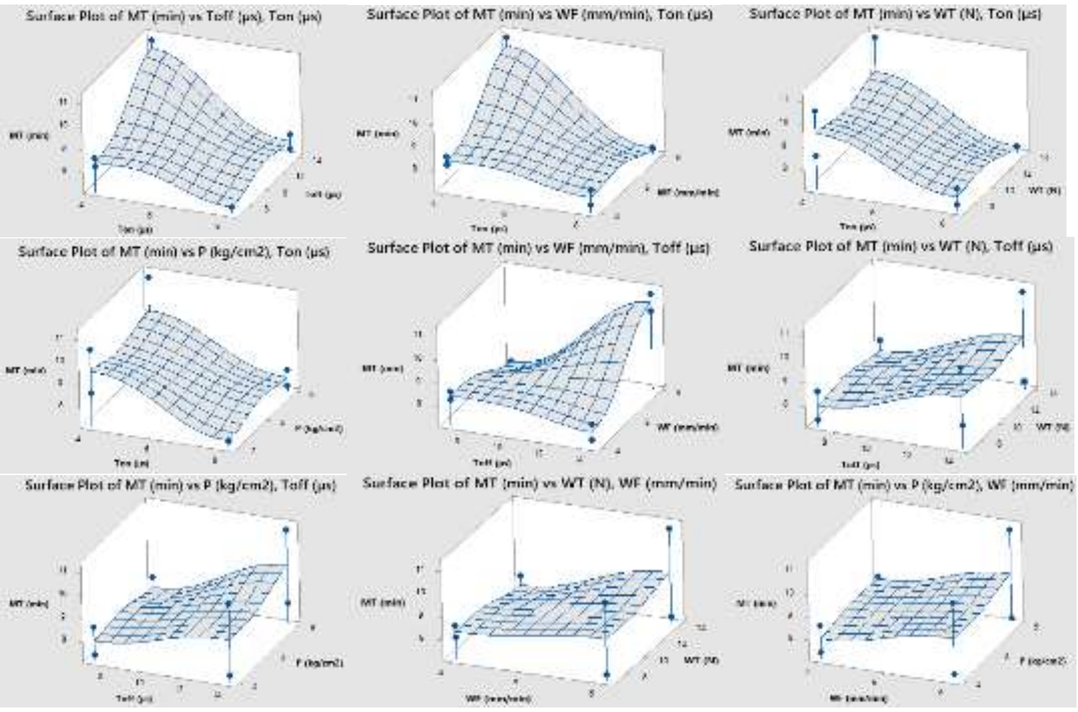
1.) KERF vs Control Parameters



Surface Plot of kerf (mm) vs Toff (µs), Ton (µs)
Surface Plot of kerf (mm) vs WF (mm/min), Ton (µs)
Surface Plot of kerf (mm) vs WT (N), Ton (µs)
Surface Plot of kerf (mm) vs P (kg/cm2), Ton (µs)
Surface Plot of kerf (mm) vs WF (mm/min), Toff (µs)
Surface Plot of kerf (mm) vs WT (N), Toff (µs)
Surface Plot of kerf (mm) vs P (kg/cm2), Toff (µs)
Surface Plot of kerf (mm) vs WT (N), WF (mm/min)
Surface Plot of kerf (mm) vs P (kg/cm2), WF (mm/min)
Surface Plot of kerf (mm) vs P (kg/cm2), WT (N)

Figure 3.7: Surface Plots of Kerf vs. Control Parameters

2.) M/c Time (min) vs Control Parameters



Surface Plot of MT (min) vs Toff (µs), Ton (µs)
Surface Plot of MT (min) vs WF (mm/min), Ton (µs)
Surface Plot of MT (min) vs WT (N), Ton (µs)
Surface Plot of MT (min) vs P (kg/cm2), Ton (µs)
Surface Plot of MT (min) vs WF (mm/min), Toff (µs)
Surface Plot of MT (min) vs WT (N), Toff (µs)
Surface Plot of MT (min) vs P (kg/cm2), Toff (µs)
Surface Plot of MT (min) vs WT (N), WF (mm/min)
Surface Plot of MT (min) vs P (kg/cm2), WF (mm/min)

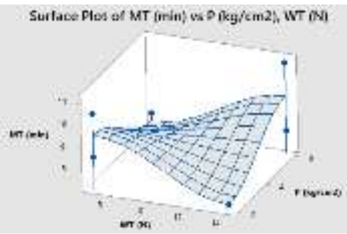
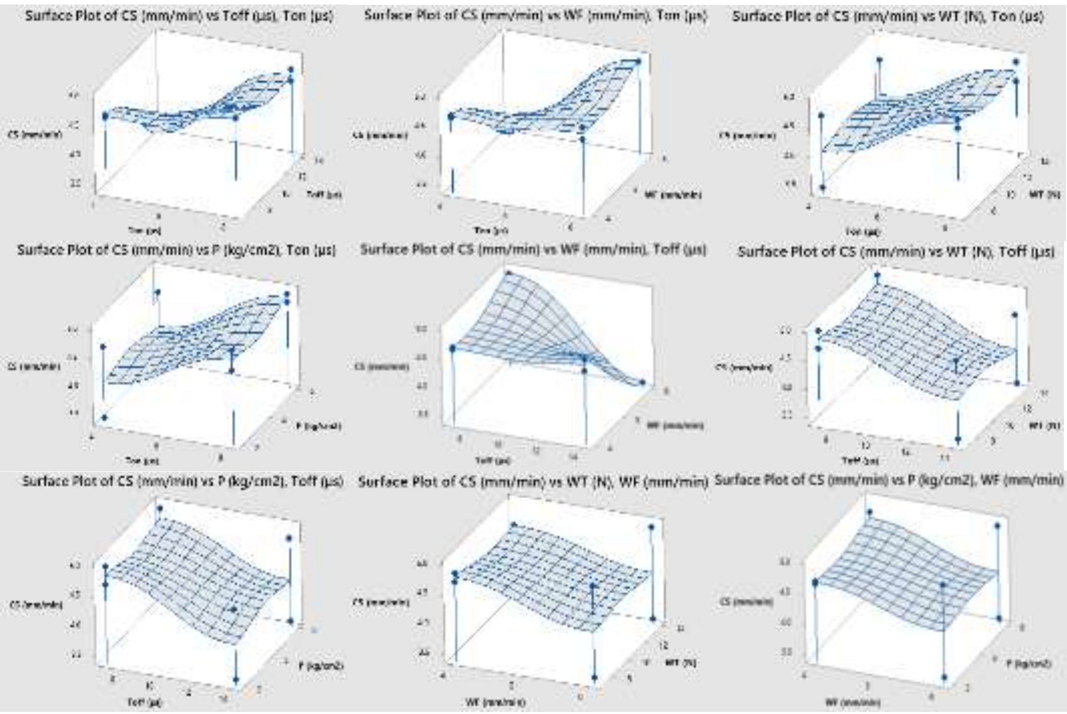


Figure 3.8: Surface Plots of M/c Time vs. Control Parameters

3.) Cutting Speed (mm/min) vs Control Parameters



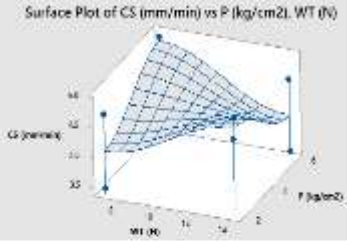


Figure 3.9: Surface Plots of Cutting Speed vs. Control Parameters

D. Optimization using desirability approach

The below graph shows optimization plot for kerf, M/c time and Cutting speed. The ultimate objective for our work was to minimize kerf, M/c time and maximize the cutting speed. Optimum values of the variables are obtained by desirability approach in order to get the minimum value of kerf, M/c time and the maximum value of cutting speed. From the graph it is clear that optimum value is obtained for the following combination of the variables Ton=7.95µs, Toff =7.0µs, WF=6.0mm/min, WT=7.0N and P=2.0 kg/cm^2.

The above results are obtained with composite desirability of 0.9641.

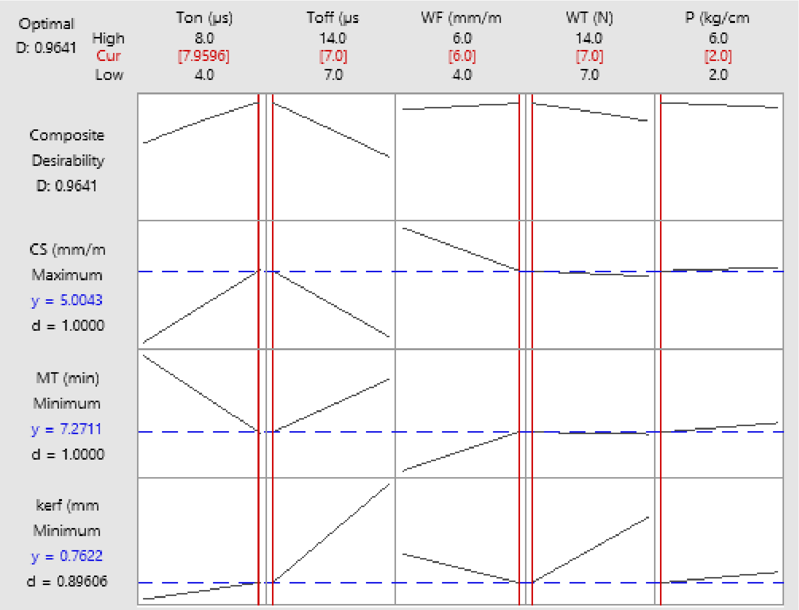


Figure 3.10: Optimization of Responses vs. Control Parameters

4. CONCLUSIONS

In this study an attempt was made to minimize KERF, M/c Time and maximize cutting speed in wire EDM. Taguchi L8 orthogonal array was used for experimental design and RSM approach was employed for finding out the optimal solution.

1.) Significant parameters and %age of contribution by the parameters

- The response KERF is affected more 56.67% by Toff, 24.80% by WT and less affected 4.84% by WF, 1.62% by Ton, 0.66% by flushing pressure P.
- The response M/c Time is affected more 56.05% by Ton, 26.21% by Toff, 14.25% by WF and less affected 2.67% by flushing pressure P, 0.04% by WT.
- The response cutting speed is affected more 45.45% by Ton, 37.45% by Toff. 16.36% by WF and less affected 0.27% by WT, 0.10% by flushing pressure P.

2.) Result of contour plots of responses vs. control parameters

- The kerf is minimum at Ton=4 - 6 and above 7µs, Toff=7 – 8.5µs, WF=5.5 mm/min and above, WT=7 – 8N and flushing pressure P=2 – 4 and 5 – 6 kg/cm^2.
- The M/c Time is minimum at Ton=7µs and above, Toff=7 – 8µs, WF=5mm/min and above, WT=12N and above, and flushing pressure P=2 – 3kg/cm^2.
- The cutting speed is maximum at Ton=4 - 5µs, Toff=12µs and above, WF=5.5 mm/min and above, WT=7 – 8N and 11 above, and flushing pressure P=2 – 3 and 5kg/cm^2 above.

3.) Effect of control parameters on responses

- As decreasing Ton with the combinations of as decreasing Toff, WF, WT and P then the kerf is decreasing
- As increasing Ton with the combinations of as increasing/decreasing Toff, WF, WT and P then the M/c Time is decreasing.

- As increasing Ton with the combinations of as increasing/decreasing Toff, WF, WT and P then the cutting speed increasing.

4.) Optimization of multi responses vs. control parameters

- Optimum values of the variables are obtained by desirability approach in order to get the minimum value of kerf, M/c time and the maximum value of cutting speed at the combination of the variables Ton=7.95µs, Toff =7.0µs, WF=6.0mm/min, WT=7.0N and P=2.0 kg/cm^2.

RFERENCES

[1] Magesh. M, et.al., “Optimization of Wire-EDM parameters to calculate MRR and measure surface finish on SS410”, IJISRT, ISSN: 2456-2165, Vol. 2, Issue 3, March-2017.

[2] Amit Kumar et.al., “Optimization of wire-cut EDM process parameters by Response Surface Methodology”, JIEI (2018) 14:821-829.

[3] Kosaraju Satynarayana et.al., “a Role of Cryogenic in Wire cut EDM Process”, E3S Web of Conferences 184, 01067 (2020).

[4] Manpreet Singh et.al., “Recent Developments in Wire EDM: A Review”, IJRMET, ISSN: 2249-5770, Vol. 3, Issue 2, Mar-2013.

[5] Junaid Ali Abbasi et.al, “Effects of wire-cut EDM process parameters on surface roughness of HSLA steel”, IJAMT, 1867-1878 (2017).

[6] Mandeep Kumar & Hari Singh, “Optimization of process parameters of wire EDM for material removal rate using Taguchi technique”, IJEMS, Vol. 3, August 2016, pp. 223-230.

[7] Pratik A Patil et.al., “Optimization of Process Parameters in Wire-EDM Using Response Surface Methodology”, Proceedings of 10th IRF International Conference, 01st June-2014.

[8] Kumaravel Subramaniam et.al. “Optimization of Wire-cut EDM Process Parameters of Al/SiO$_2$ Composites Using Taguchi Method”, SAE Technical Paper 2020-28-0426, 2020.

[9] Asfana Banu et.al., “Analysis of WEDM Process Parameters on Surface Roughness and Kerf using Taguchi Method”, IJEMM, (2017) 2(4) 103-109.

[10] Neeraj Sharma et.al., “Multi Quality Characteristics of WEDM Process Parameters with RSM”, Procedia Engineering, Vol. 64, 2013, pp. 710-719.

[11] Kingshuk Mandal et.al., “Experimental Investigation of Process Parameters in WEDM of AL7075 alloy”, Manufacturing Rev. Vol. 7, (2020) 30, pages 9.

[12] Nagarajan Lenin et.al., “Optimization of Process Parameters for WEDM of Al-LM25/Fly Ash/B4C Hybrid Composites Using Evolutionary Algorithms: A Comparative Study”, Metals 2021, 11, 1105.

[13] Shubham Sharma et.al., “Review on Process Parameters of WEDM”, A Journal of Composition Theory, ISSN: 0731-6755, Vol. XII, Issue VII, July 2019.

[14] Nitin Kumar Gupta et.al., “Revealing the WEDM Process Parameters for the Machining of Pure and Heat-Treated Titanium (Ti-6Al-4V) Alloy”, Material 2021, 14, 2292.

[15] K Raju et.al., “Optimization of WEDM Process Parameters in Al2024-Li-Si$_3$N$_4$ MMC”, Research Article/Open Access, Vol. 2022, ID 2903385.

[16] Mohammad Taha et.al., “Optimization of Process Parameters on EN 34 Steel for WEDM Operations”, NCETER, 2021, Vol. 09, Issue 11.

[17] Mangesh R. Phate et.al., “Analysis of Machining Parameters in WEDM of Al/SiCp20 MMC Using Taguchi-Based Grey-Fuzzy Approach”, Vol. 2019, ID 1483169.

Author’s Profile

M Veeranjaneyulu[1],
Research Scholar, Dept. of Mechanical Eng.,
OPJS University, Churu, Rajasthan

Dr. Deepak Dalal[2],
Assistant Professor, Dept. of Mechanical Eng.,
OPJS University, Churu Rajasthan